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SPECIFICATION FOR QUENCHED AND TEMPERED ALLOY STEEL FORGINGS FOR PRESSURE VESSELS

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SPECIFICATION FOR QUENCHED AND TEMPERED ALLOY STEEL FORGINGS FOR PRESSURE VESSELS

0. FOREWORD

0.1 This Indian Standard was adopted by the Bureau of Indian Standards on 23 July 1987, after the draft finalized by the Steel Forgings Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 Keeping in view the special application of quenched and tempered alloy steel forgings for pressure vessels, such as reactor systems, this standard has been formulated. However, for steel forgings used in the construction of fired and unfired pressure vessels, IS : 9683-1980* may be followed. The steel forging covered in this standard are weldable too. It is hoped that this standard will also help users to procure the required quality of forgings desired by them.

0.3 In the preparation of this standard, assistance has been derived from the following standards:

ASTM A 434-1981 Specification for steel bars, alloy, hot-wrought or cold-finished, quenched and tempered. American Society for Testing and Materials.

ASTM A 508-1984 Specification for quenched and tempered vacuum treated carbon and alloy steel forgings for pressure vessels. American Society for Testing and Materials.

JIS G 3204-1982 Quenched and tempered alloy steel forgings for pressure vessels. Japanese Industrial Standards Committee.

0.4 This standard contains clauses **8.1**, **9.2.2.2**, **10.1** and **10.2** which call for agreement between the purchaser and the manufacturer.

*Carbon and low alloy steel forgings for fired and unfired pressure vessels.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers the requirements for quenched and tempered alloy steel forgings for pressure vessels, such as those used in reactor system. Specifically, it covers forgings for vessel closures, shells, flanges, tube sheets, rings, heads and similar parts.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions of forging terms shall be as given in IS : 1956 (Part 6)-1976†.

3. SUPPLY OF MATERIAL

3.1 General requirements relating to the supply of material shall be as laid down in IS : 1387-1967‡.

4. MANUFACTURING PROCESS

4.1 The forgings shall be manufactured from killed steel made by any one of the primary processes like open hearth, basic oxygen or electric furnace and may be followed by secondary steel making processes.

4.2 Sufficient discard shall be made from each ingot to secure freedom from harmful piping and segregation.

4.3 Forgings shall be mechanically hot worked by a suitable process to ensure adequate deformation throughout the sections.

4.4 Heat Treatment

4.4.1 After hot working, the forgings shall be cooled so as to achieve complete transformation of austenite without any injurious effect like cracking or distortion.

4.4.2 All the forgings shall be heat treated by quenching and tempering. The recommended temperatures for heat treatment are given in Table 1.

*Rules for rounding off numerical values (*revised*).

†Glossary of terms relating to iron and steel : Part 6 Forging (including drop forging) (*first revision*).

‡General requirements for the supply of metallurgical materials (*first revision*).

TABLE 1 TEMPERING TEMPERATURE

(*Clause* 4.4.2)

GRADE	TEMPERING TEMPERATURE (°C) *Min*
(1)	(2)
I A	650
I B	620
II A	650
II B	620
IV	610

4.4.2.1 Subsequent to tempering, unless otherwise specified by the purchaser, the forgings shall be slow cooled from the tempering temperature. However, accelerated cooling may be applied to the forgings when the test piece is heat treated according to **4.4.3**.

4.4.3 When the purchaser desires particular heat treatment of the test piece, for example, stress relieving or any other condition, the manufacturer shall prepare the test piece from the test specimen as specified in **9.2**. The test piece shall be heat treated in accordance with the purchaser's direction providing the details of the heat treatment conditions such as heat treatment temperature, soaking time, cooling rate and such other details pertinent to the specific application.

5. CHEMICAL COMPOSITION

5.1 Ladle Analysis — The ladle analysis of the steel when made in accordance with relevant parts of IS : 228* shall be as given in Table 2.

TABLE 2 CHEMICAL COMPOSITION OF ALLOY STEEL FORGINGS

GRADE	C (*Max*)	Si (*Max*)	Mn	Ni	Cr	Mo	V (*Max*)	S (*Max*)	P (*Max*)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
I A I B	0·25	0·40	1·20 to 1·50	0·40 to 1·00	0·25	0·45 to 0·60	0·05	0·030	0·030
II A	0·27	0·40	0·50 to 1·00	0·50 to 1·00	0·25 to 0·45	0·55 to 0·70	0·05	0·030	0·030
II B	0·27	0·40	0·50 to 1·00	0·50 to 1·00	0·25 to 0·45	0·55 to 0·70	0·05	0·030	0·030
III	0·23	0·40	0·20 to 0·40	2·75 to 3·90	1·50 to 2·00	0·40 to 0·60	0·03	0·020	0·020

*Methods for chemical analysis of steels.

5.2 Product Analysis — Product analysis shall be carried out on finished forgings. The samples for product analysis shall be taken from the forging or from a full size prolongation. Samples may be taken from (1) midway between the centre and the surface of solid forgings, (2) midway between the inner and outer surfaces of hollow forgings, or (3) from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 2 within the permissible variations of Table 3.

TABLE 3 PERMISSIBLE VARIATIONS IN PRODUCT ANALYSIS

ELEMENT	LIMIT OR MAXIMUM SPECIFIED RANGE, PERCENT	PERMISSIBLE VARIATION OVER THE SPECIFIED MAXIMUM LIMIT OR UNDER THE SPECIFIED MINIMUM LIMIT PERCENT CROSS-SECTIONAL AREA				
		Up to and Including 1 390 cm²	Over 1 390 Up to 2 580 cm² Including	Over 2 580 Up to and 5 160 cm² Including	Over 5 160 Up to 10 320 cm² Including	Over 10 320 cm²
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Manganese	Up to and including 0·90	0·04	0·05	0·06	0·07	0·08
	Over 0·90	0·06	0·07	0·08	0·08	0·09
Nickel	Up to and including 1·00	0·03	0·03	0·03	0·03	0·03
	Over 2·50 to 4·00 (including)	0·07	0 07	0·07	0·07	0·07
Chromium	Up to and including 0·90	0·04	0·04	0·05	0·05	0·06
	Over 0·90 to 2·10 (including)	0·07	0·07	0·07	0·07	0·07
Molybdenum	Up to and including 1·00	0·04	0·05	0·06	0·07	0·08
Vanadium	Up to and including 0·10	0·01	0·01	0 01	0·01	0·01

NOTE 1 — Product cross sectional area taken at right angles to the axis of the original ingot or billet is defined as:

a) Maximum cross-sectional area of rough machined forging excluding boring.

b) Maximum cross-sectional area of the unmachined forging, or

c) Maximum cross-sectional area of the billet, bloom slab.

NOTE 2 — Product analysis for carbon, phosphorus, sulphur and silicon shall conform to the requirements of Table 2.

6. MECHANICAL PROPERTIES

6.1 The mechanical properties of the forgings shall be as given in Table 4.

TABLE 4 MECHANICAL PROPERTIES OF STEEL FORGINGS

(*Clause* 9.2.1)

Grades	Tensile Test				Impact Test		
	Yield Point or 0·2 Percent Proof Stress, MPa (*Min*)	Tensile Strength, MPa	Elongation, Percent (*Min*)	Reduction in Area, Percent (*Min*)	Test Temperature °C	Charpy Absorbed Energy	
						Mean value of three test pieces (*Min*)	Individual value (*Min*)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I A	345	550 to 725	16	38	0	40	34
I B	450	620 to 795	14	35	20	47	40
II A	345	550 to 725	16	38	0	40	34
II B	450	620 to 795	14	35	−20	47	40
III	490	620 to 795	18	48	−30	47	40

7. APPEARANCE

7.1 The forgings shall have a workmanlike finish and be free from defects which are detrimental to practical use.

8. SHAPES, DIMENSIONS AND TOLERANCES

8.1 Shapes, dimensions and tolerances on the forgings shall be as agreed to between the purchaser and the manufacturer.

9. TEST

9.1 Chemical Analysis

9.1.1 The general requirements for chemical analysis and sampling method of specimen for ladle analysis and product analysis shall be in accordance with relevant parts of IS : 228*.

9.2 Mechanical Tests

9.2.1 Testing methods and types of test piece for mechanical test (tensile test IS : 1608-1972†, impact test IS : 1499-1977‡, hardness test IS : 1500-1983§) shall be in accordance with the specification of respective standards.

*Methods for chemical analysis of steels.

†Method for tensile testing of steel products (*first revision*).

‡Method for Charpy impact test (U-notch) for metals (*first revision*).

§Method for Brinell hardness test for metallic materials (*second revision*).

9.2.2 *Number of Specimen and Test Pieces* — Number of specimen and test pieces shall be as given in **9.2.2.1**, **9.2.2.2** and **9.2.2.3**.

9.2.2.1 Sampling method of specimen for the forgings shall be as given in Table 5. However, when many steels are forged and heat treated successively at the same chance, all of them may be deemed at a single forging.

TABLE 5 SAMPLING METHOD OF SPECIMEN

Weight of Single Forging at the Time of Heat Treating, kg	Sampling Method of Specimen	Lot
(1)	(2)	(3)
Up to 500	One piece per lot	A lot consists of steel of the same ladle, same heat-treatment and similar size
500 and over	100 %	—

9.2.2.2 The specimen shall be taken from the main body of a forging or its prolongation. em However, a separately forged specimen may be prepared to submit to the tests when the following requirements are satisfied by agreement between the purchaser and the manufacturer:

a) The steel ingot, slab or billet made from the same molten steel as used for the forgings and similar type of hot working shall be carried out.

b) The largest forming ratio shall not be more than the smallest forming ratio of the forgings.

c) The heat treatment shall be performed at the same chance of the forging itself within the same furnace.

d) The thickness shall not be less than the largest thickness of the forgings.

9.2.2.3 One set of test pieces shall consist of one tensile test piece and three impact test pieces. The number of test pieces shall be as shown in Table 6.

9.2.3 *Location of Sampling of Test Piece* — The location of sampling test piece shall be as given in **9.2.3.1** and **9.2.3.2**.

9.2.3.1 For upset disc forgings and ring forgings, the longitudinal axis of the test specimens shall be in the tangential direction. For all other parts, the longitudinal axis of the specimens shall be parallel to the direction of major working (in case of a shaft, for example, the direction for

major working is perpendicular to the axis of the shaft) of the forging. When due to constraints of the geometry, it is not possible to take out specimens from specified location, for example in case of shafts of small diameter or ring of small wall thickness, the specimens shall be taken as near the specified location as possible.

TABLE 6 NUMBER OF TEST PIECES

(*Clause* 9.2.2.3)

SHAP	WEIGHT OF SINGLE FORGING AT THE TIME OF HEAT TREATING, kg	WHOLE LENGTH OR HEIGHT mm	NUMBER OF TEST PIECES
(1)	(2)	(3)	(4)
Shaft shaped or cylindrical forging	Up to 3 000	To 3 000 including	One set
		Over 3 000	One set each on both ends
	Over 3 000	—	One set each on both ends
Ring-shaped forging	—	To 1 000 including	One set
	—	Over 100	Two sets at one end
Disc-shaped forging	—	To 400 including	Two sets at one end
	—	Over 400	

NOTE 1 — When two sets are taken from one end of the forging, the location of sampling of test piece shall be positioned at an angle of 180° to each other on the same side face.

NOTE 2 — When one set each is taken from both ends of the forging, the location of sampling of test piece shall be positioned at an angle of 180° to each other.

9.2.3.2 The location of sampling of test piece shall be as given below:

a) The centre of the test piece shall be located not less than $\frac{1}{4}$ T apart from one of the heat treated surfaces and also not less than T away from the second heat treated surface where T denotes the largest thickness or diameter of the forging or separately forged specimen at the time of heat treating. For applying this method, the thickness of the forging, as a rule, shall not exceed the values shown in Table 7.

b) When the forging has so intricated a shape as to be formed or machined into the similar shape of product prior to heat treatment the centre of test piece shall be located apart from the heat treated surface not less than the largest distance (T max) between the high tensile stress surface which is previously designated and the heat treated surface nearest to the surface and as well not

less than 2 T max away from the second heat treated surface. However, the centre of the test piece shall be located not less than 20 mm apart from any one of heat treated surface and not less than 40 mm away from the second heat treated surface. When T max is less than 20 mm, it shall be deemed as 20 mm.

TABLE 7 APPLICABLE RANGE OF THICKNESS

[*Clause* 9.2.3.2(a)]

Designation of Grade	Applicable Range on Thickness, mm *Max*
(1)	(2)
I A, II A	200
I B, II B	150
III	1 000

c) A thermal buffer ring, at least $T \times T$ in cross section, or sections of such a ring at least 3 T in length, shall be welded to the test end of a forging prior to heat treatment for mechanical properties. Tne buffer material may be any weldable carbon or low-alloy steel which shall be joined to the forging with partial penetration type weld which completely seals the buffered surface. The test coupons shall be removed from the forging in the region buffered by the ring or ring segments. If ring segments are used, the test coupons shall be removed from the forging in the area under the centre 1/3 of the buffer ring segment length. In either case, the test specimens shall be located to a minimum distance 15 mm from the buffered surface of the forging and at least $\frac{1}{4}$ T from a quenched surface of the forging.

10. INSPECTION

10.1 The manufacturer shall afford the purchaser's inspector, all reasonable facilities necessary to satisfy him that the material is being produced and finished in accordance with this specification. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to between the purchaser and the manufacturer.

10.2 Repair by Welding — The defect detected through the inspection may be repaired by welding upon the agreement between the purchaser and the manufacturer.

11. ULTRASONIC TESTING

11.1 Forgings shall be ultrasonically tested to the requirements of standards which may be agreed mutually between the manufacturer and the purchaser.

12. RETEST

12.1 If the results of mechanical tests do not conform to the requirements specified, retests are permitted as outlined below:

a) If a test specimen fails to meet the minimum specified requirement due to a flaw other than a rupture, crack or flake, a single retest shall be allowed.

b) In case of failure of mechanical test specimens to conform to the minimum requirements specified, the manufacturer may reheat-treat the forging. Testing after reheat-treatment shall consist of the full number of specimens taken from locations complying with the specification or order.

c) If the average impact energy value meets specification requirements and the energy value for one specimen is below the specified minimum value for individual specimens prescribed in Table 4, a retest is permitted of two impact specimens from a location adjacent to the specimens that has failed. Each of the retested specimens must exhibit an energy value equal to or greater than the minimum average value prescribed in Table 4.

13. MARKING

13.1 Unless agreed otherwise, each forging shall be legibly low-stress stamped with the grade of material, heat number or identification mark and the trade mark of the manufacturer.

13.1.1 When the forgings are ordered in fully machined condition, the identification marks shall be transferred in the presence of the purchaser after full machining.

13.1.2 The forgings may also be marked with the Standard Mark.

NOTE — The use of the Standard Mark is governed by the provisions of the Bureau of Indian Standards Act, 1986 and the Rules and Regulations made thereunder. The Standard Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by BIS and operated by the producer. Standard marked products are also continuously checked by BIS for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers, may be obtained from the Bureau of Indian Standards.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2